31 May 1966

Van Vleck Observatory

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Final Report for NASA Grant NGS 716/07-006-002

Studies of Planetary Physics

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Introduction

During the 1964 and 1965 apparitions of Jupiter, we operated an observing station searching for Jovian radio emission between 3 and 8 mc/s. The concurrent lull in solar activity held out the promise that ionospheric effects would not be prohibitive, even at such "long decametric" wavelengths.

Most students of Jupiter's radio noise storms have used wavelengths about ten to twenty meters ("short decametric") for synoptic observations. Their results may be described by certain features, such as the dependence of emission upon Jupiter's longitude. These features have been reviewed extensively (for example, Douglas 1964; Smith and Carr 1964). The question arises what happens to these features as the wavelength increases? Extrapolation from the short decametric data was unclear. Those observations that had been attempted (Ellis, 1962; Smith et al., 1965) were enough to give the tantalizing suggestion the descriptive properties changed markedly. But there was little agreement on what changes occurred . For example, the flux densities reported by Smith and his co-workers were ten to one hundred times that recorded by Ellis. Our experiment, then was intended to sweep away all these uncertainties. Our results are rather less sweeping. Roughly speaking, our data lean toward Ellis's, however our sensitivity was not high enough to see activity as often as he. In detail, the results are discussed in the last section, following a description of the equipment and the criteria whereby Jupiter was identified.

Equipment and Identification

There are several annoyances common to radio astronomy: poor directivity, ionospheric effects, interference, and so on. But as the wavelength increases toward one hundred meters, these sores swell up approaching the unbearable. Therefore in the design of our equipment several features were thought to be desirable. The first was that an interferometer must be used, as an aid to the identification of the source on Jupiter. The second was high selectivity, for which the receiver band-pass was restricted to about 2 kc/s. The observations should cover as many frequencies as possible, to determine the spectrum; ideally, a swept frequency receiver should be used. Unfortunately, the narrow bandwidth required to avoid stations, made this impractical and we chose several discrete channels. However, it wasn't possible to tell at the outset what frequencies the ionosphere and interference would permit us to use. Therefore, we chose to design the antennas and the interferometer electronics to be broad band, which permits tuning any channel receiver to any frequency in the 3 - 8 mc/s range.

The system resulting from such considerations was this: a two element phase-switching interferometer. The base line was either 800 or 2000 meters, E-W. The antennas were compound six-wire dipoles, which have fairly mild changes in impedance over the 3 - 8 mc/s range. The phase-switch output was fed to communications receivers (up to six in number). The signal then passed through a phase sensitive detector (2 sec. time constant), and then recorded on strip-chart recorders. During 1965, a system of reed switches was added which disconnected the integrating capacitor in the detector during a burst of atmospherics. Thus, by omitting sferics, the sensitivity during the summer of 1965 was about three or four times that during 1964.

The advantages of this system were its simplicity and flexibility; the most serious objection was the low sensitivity, due mostly to the lack of antenna gain. We experimented with longer time constants (Ellis used three minutes), but without success. Evidently, extremely low level interference, or some other cause, produced a wandering base line with a time scale similar to the fringe period. In consequence of this short coming, we failed to record much of the low level activity reported by Ellis, by Erickson's antenna at 26 mc/s (Stone et al., 1964) or by Clark and Dulk (1966) at 10 mc/s .

At the longer decametric wavelengths, one receives a great deal of radio noise. The galactic background is high, sferics are very common, and interference from man made sources is often very severe. And there may be other causes. How does one prove that a given noise record is produced by Jupiter? Perhaps the best way is to obtain the position of the source within satisfactorily small limits. If Jupiter is within this solid angle, and if the source follows the motion of Jupiter in hour angle during the night, and in right ascension during the season, then there is reason to suppose the source is associated with the planet, or his satellites. Our instrument records the product of the flux density and the cosine of phase angle of the source with respect to the interferometer fringe maxima. Strictly speaking, our system doesn't fulfill the rigorous conditions; but under favorable conditions the periodic variations of the record give a good fit to that period expected from the diurnal motion of Jupiter. Conditions are rarely ideal however, and on most events there may be some cause to question the identification.

It should be emphasized that an observer was on hand. We had originally thought that we could use the "aural monitoring" of Smith, Carr and their colleagues. Unfortunately the storms were so weak--much less than the galactic background--that they were inaudible. The observer's chief function then became one of testing any activity seen on the recorders to see whether it might be weak interference or some other terrestrial cause.

In view of the uncertainties involved we grade the identification of activity. Grade A contains events most likely to originate from Jupiter, although rigorously, the word "certain" may be too strong. A grade of B+ indicates an event possibly Jupiter, and we think it is. There also occur a number of B- events, which are possibly Jupiter, but we doubt it. A very few events are grade B—i.e. we can't decide. Generally, the B grades contain storms that last too short a time to give a precise period, although there may be other reasons for doubt, such as peculiar activity at other times during the night. We also define an identification of grade S — these are hours long events often quite strong, and seen only in the summer of 1964. The fringe pattern is often quite irregular, especially after sunrise, when Jupiter was near transit. We do not know the source of this noise, but it doesn't appear to be terrestrial.

In analyzing the data, the different grades are kept separate. We feel that the sum of the A and B+ data should give the best picture of Jupiter's properties.

Perhaps the "Meridian Noise" should be mentioned briefly. Quite often we observe a strong noise source which gives marked deflection on the phase-sensitive recorders, but this source does not partake of the diurnal motion of the sky.

Although the record may wander and change sign in a cyclical way, thus looking roughly like Jupiter, the record is rarely symmetrical, and there are long intervals where the source is nearly fixed. Because we may tune a channel anywhere, it has been possible, in a few cases, to track the phase deflection as a function of frequency. Such data show the source to be located near the meridian. While a careful test hasn't been made, there seems to be a strong tendency for these Meridian Noise Storms to occur several hours following a rise in the magnetic-K index to 3 or more. These events may have interest in themselves; suffice it to note that these events could be mistaken for Jupiter, especially using the aural monitoring technique.

Results

Our 1964 observing season ran from July 1, 1964 through January 20, 1965. About two-thirds of the nights were quiet, or moderately so. On these, Jupiter activity would be identified, probably, if its flux density exceeded 2×10^{-21} w/m^2 cps. (depending on frequency). This threshold is much larger than that used by Ellis, and it is not at all surprising that we see activity only rarely. It turns out that many nights are much quieter than average; on these the flux limit may be 1×10^{-21}. Several of our Jupiter events have continuum fluxes near this value, but we cannot easily estimate the amount of time for which conditions are that good. Therefore, we cannot offer occurrence probabilities.

During the 1964 season, we recorded this number of events:

Identification grade	A	10
	B+	11
	B	6
	S	6
	B-	(14)
total		47

There are several properties one may seek: dependence upon frequency, upon radio longitude, upon Io's longitude; the character of the storms, and so on.

Character.

The short decametric radiation is famous for its bursts, although continuum is sometimes seen. It is this rough character that gives rise to the "swishing" sound. The most striking feature of our events is the smooth continuum which may vary little or none in power for twenty minutes or so. A typical event, lasting an hour or more, has these long periods of continuum, separated by gaps of ten or more minutes. Very often rises or enhancements occur, lasting one to three minutes. On weaker storms, only the enhancements seem to show. Occasionally, bursts, on a time scale of seconds are seen. If the storm shows on more than one channel, active and quiet periods tend to occur concurrently; drift in frequency is rare.

Frequency.

We usually operated four or five channels, typically 3.5, 4.1, 4.7, 5.5 and 6.6 mc/s. Taking only those A, B+ and B events for which four or more channels had sufficient sensitivity (16 events), nine were not recorded below 5.5 mc/s.; five were seen on most channels, and only two were restricted to frequencies below 4.7 mc/s.

Two broad band storms showed patches of emission at 3.5 mc/s. The interesting point is that the flux density was very much lower, perhaps one-tenth, that received above 5 mc/s. The flux density at 4.1 was also low. The only reason we could see such activity at all in our data is that the flux limit at 3.5 mc/s was much lower than at higher frequencies, due possibly to the preferential absorption at low angle sferics and interference. The signal from Jupiter is absorbed too; but the usual estimates suggest a factor of no more than a two to three, for whatever they're worth.

Longitude.

Most of the grade A events occur between λ_{III} between 330° and 30°; there is a secondary peak at $\lambda_{III} = 155°$. Adding the B+ events, the fourth quadrant becomes the most favored, especially 300° - 0°; several additional events occur near 155° and three near 110°. The B- events almost always occur near 90° to 150° -- rather odd since we think they aren't Jupiter. The grade S events last so long that they fill in most longitudes.

An interesting feature for any group, or for all together: No activity was detected between 200° and 240°, except two brief B- events.

Influence of Io.

Except for the events occurring between λ_{III} 150° and 170°, there is a very strong tendency for Io to have a position angle (from superior conjunction) between 200° and 250°. However, the storms between 150° and 170° show no preference for Io's position. The reader must be warned that there are dangerously few events. If further work sustains these impressions, they bear an inverse relation to the short decametric data. For these, it is the second quadrant source which requires Io to be at an appointed spot ($\phi_{Io} \sim 90°$); emission from the "main source" (240°$\pm$) is more likely when Io's position is near 240°, but the effect is not so strong.

In conclusion, we have taken as much care as we can to avoid contamination by false identifications. Partly as a result of this, and partly because of the wide frequency range covered, we obtained records of relatively strong activity only. The features we obtain include these: (1) the power received from Jupiter seems to fall off markedly below 4 or 5 mc/s. We suggest that the effect is real, despite possible ionospheric effects. (2) The longitude profile has a broad peak of activity between 300° and 30° which is associated with Io's position near 230°; and a second peak near 150° longitude which is less sensitive to Io's position. (3) activity was seen to occur at any longitude except 200° to 240°.

Analysis of 1965 data should augment, and possibly change, the features mentioned. Provisionally, we seem to see a picture at long wavelengths in some ways complementary to the well known view, seen at shorter wavelengths.

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